

10 Radiologic Analysis of Cadaver Impact Injuries

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Abstract

This paper examines the ability of conventional x-rays to document human cadaver injuries resulting from blunt impacts. Ten cadavers utilized in sled impact tests were examined for thoracic fractures with data from radiographs and autopsy examinations. Radiographic interpretations significantly underestimated both the severity and number of injuries when compared with necropsy findings. Two emerging radiographic modalities with increased resolution and accuracy, Magnetic Resonance Imaging and Computed Tomography, were investigated and evaluated. Although expensive, these techniques exhibit a potential for improved diagnosis and analysis of cadaver impact injuries.

Introduction

During cadaver impact testing, emphasis is placed on the accurate and repeatable recording of sensor data (e.g., accelerometers, force and pressure transducers, potentiometers, and strain gages). Placement of instrumentation is referred to both a local anatomical landmark and a reference global coordinate system. When combined, radiographs and autopsy examinations can successfully identify that an injury has occurred. They fail, however, to determine the exact in-situ location of the trauma. Since radiographs are two-dimensional representations of the three-dimensional tissue, they possess limited precision for the placement of sites of trauma. Autopsy investigations involve in-vitro inspection of thoraco-abdominal organs and tissue. The in-vivo locations of fractures or lesions cannot be determined after the evisceration has been performed. In order to correlate measured engineering parameters with injuries recorded at a specific location, more precise means of documenting injuries need to be developed. When as a supplement to autopsy and radiography findings, Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) can provide an accurate and thorough means of detecting, locating, and classifying both hard tissue and soft tissue damage.

X-rays

Since the inception of cadaver impact testing, conventional x-rays have been used to document bone fractures, to locate and to verify instrument mounting sites, and to provide an overall indication of skeletal quality. The formation of a radiographic image begins with the emission of photons from an x-ray tube. These photons enter the subject where they are either scattered, absorbed, or transmitted without interaction (see Figure 1). Transmitted and deflected

photons are recorded by a detector which is processed and ultimately developed as a x-ray film. The film provides a measure of the probability that a photon has passed through the subject with or without interaction. Therefore, this probability depends upon the sum of the x-ray attenuating properties for all the tissue the photon traverses. The resulting image is a two-dimensional projection of all the tissues, which are distributed in three-dimensions, along the path of the x-rays. Because the films are merely projections of the tissue, interpretation of the radiographs is a very skilled task and involves both the perception of small differences in contrast and detail as well as the recognition of abnormal patterns of injury (Webb, 1988).

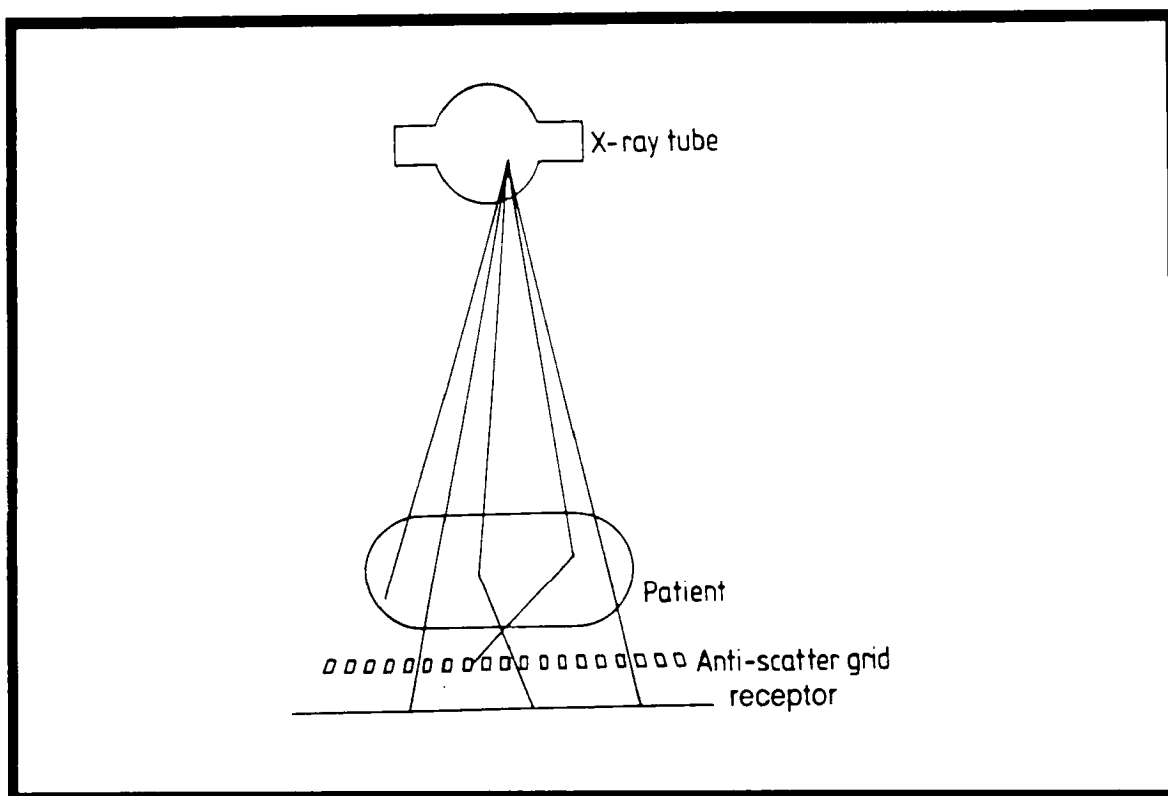


Figure 1. Components of X-ray Imaging System (Webb, 1988)

Rib fractures are primarily identified on x-ray films by either a break in the continuity of the bone or by a lesion in the periosteum, the outer bone covering. In our study, cadaver bone fractures have been less conspicuous than those associated with living patients. This can be attributed to the fact that the living body reacts to the trauma and begins repairing the fracture. A hematoma may develop in the vicinity of the fracture. In addition, the break will form a knot of calcium around the fracture at the initiation of the healing process. Both the hematoma and calcium knot are readily identified with x-rays.

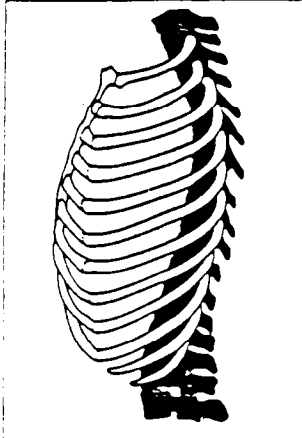
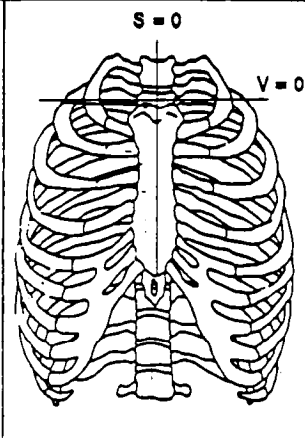
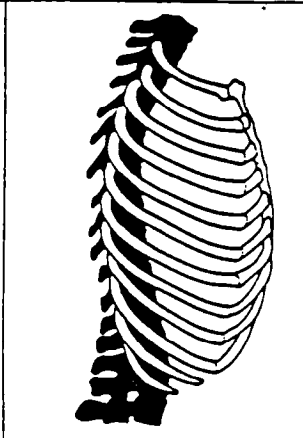
Autopsy Examination

External or superficial palpation of the thorax for fractures is extremely difficult due to skin and subcutaneous tissue overlying the ribs. During an autopsy,

RIB FRACTURE REPORT FORM

TEST NO. _____

Please mark fractures on diagrams below, and then list description of injury in table.

		
Left	Center	Right

*	<u>Rib No.</u>	<u>Total Number of Fractures</u>	<u>Fracture No.</u>	<u>Aspect</u>	<u>S(in.)</u>	<u>V(in.)</u>
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Next, a bone saw is used to cut the lateral rib cage and collar bone and facilitate removal of the entire breast plate. Fracture sites are again identified and compared with the in-situ measurements (see Figure 3). Special attention is given to the type of fracture (e.g., simple, oblique, displaced, or segmented) and to the presence of localized soft tissue trauma. With sufficient detail and measurements, the potential mechanism of injury can be surmised from the nature of the break.



Figure 3. Detection of Rib Fractures during Autopsy.

Comparison of Radiograph Interpretation with Autopsy Examination

To quantify the efficacy of x-rays, radiographs of post-impact cadavers were compared with the corresponding autopsy rib fracture results for 10 cadavers. Ten cadavers was chosen to be the minimum sample size yielding statistically significant results. All human surrogates had been utilized in sled impact tests at velocities of 20-30 mph and nominal deceleration levels of 20 g's. A statistical Kappa test was performed to analyze the fracture data. Each rib was assigned a number one (1) through (12) beginning with the most superior rib. Regardless of body orientation (left-right), fractures for each rib number of each cadaver were summarized. Radiology results were compared to autopsy findings with the aid of a simple chart (see Figure 4). For each documentation method (i.e., x-ray or autopsy), successful identification of a fracture for a given rib was identified with a plus sign (addition or positive symbol). If no fracture was identified, a minus sign (subtraction or negative symbol) was assigned to the rib number for the particular method. An individual chart was tabulated for each rib number and included the data from all ten cadavers. An example may best illustrate the test. For a specified rib number on a given cadaver, suppose a fracture was identified with autopsy but not with x-ray. Referring to Figure 4, the value one (1) would be added to the matrix location identified as "c". If autopsy and x-ray both recorded no fracture, the value one would be added to the "d" matrix site.

		Autopsy		
		+	-	
X-ray	+	a	b	a+b
	-	c	d	c+d
		a+c	b+d	a+b+c+d

Sensitivity $P(-Xray | +Autopsy)$
 Specificity $P(+Xray | +Autopsy)$
 +PV $P(+Autopsy | +Xray)$
 -PV $P(-Autopsy | -Xray)$

Figure 4. Statistical Kappa Test.

Listed in Table 1 are the numerical results from the Kappa tests which yielded four statistical parameters for each rib number. The reference or standard for defining a fracture in the Kappa test was chosen to be the autopsy findings. Only the specificity was dealt with in this paper, although, the other parameters are presented.

Rib	-Xray no break Sensitivity	+Xray break Specificity	break +Xray +PV	nobreak -Xray -PV
1	0.9375	0.2500	0.5000	0.8333
2	1.0000	0.0000	-	0.4500
3	1.0000	0.1176	1.0000	0.1667
4	1.0000	0.2143	1.0000	0.3529
5	1.0000	0.4615	1.0000	0.5000
6	1.0000	0.7273	1.0000	0.7500
7	0.8571	0.3846	0.8333	0.4286
8	0.8333	0.8750	0.7778	0.9091
9	0.8571	0.8333	0.7143	0.9231
10	1.0000	0.6667	1.0000	0.9444
11	1.0000	0.0000	-	0.9500
12	1.0000	-	-	-

Table 1. Kappa Test Statistical Parameters

Figure 5 presents the specificity data as a bar chart and illustrates two conspicuous observations. First, the overall documentation of rib fractures with x-rays is poor. Second, the percentage of detected lower numbered rib breaks (1-5) is significantly lower than the higher numbered rib fractures (6-10).

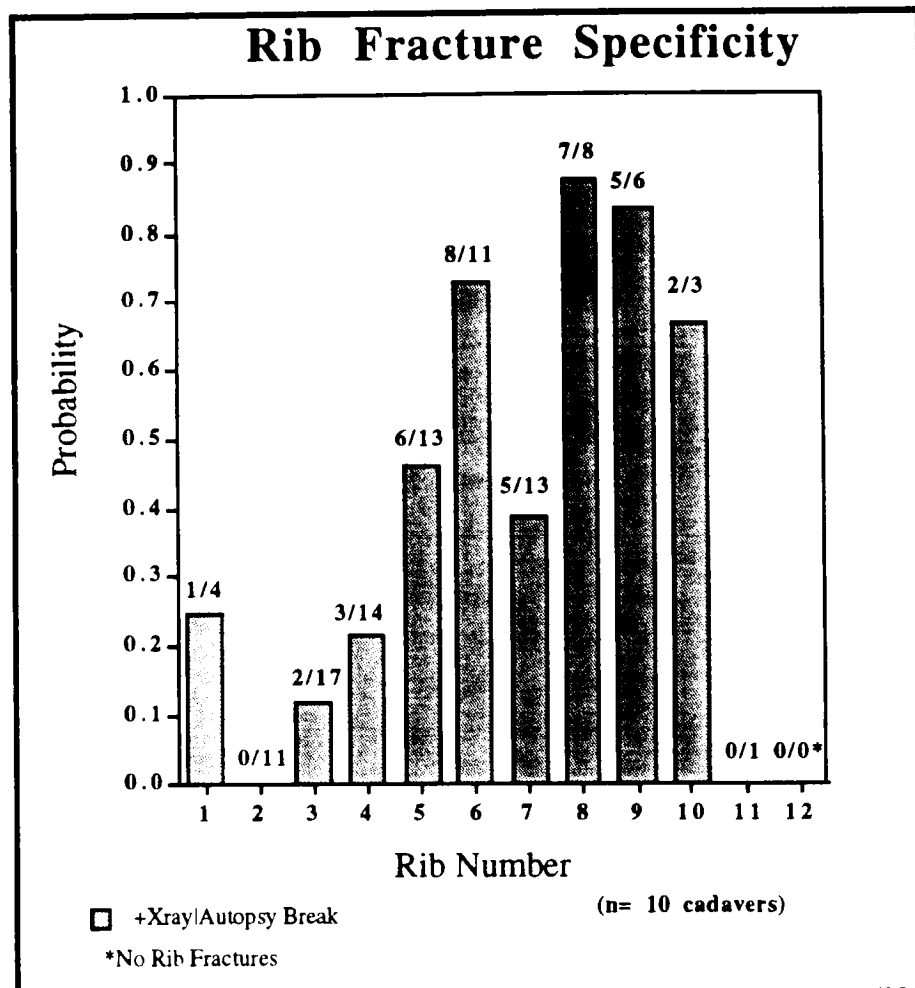


Figure 5. Rib Fracture Specificity

The anatomy of the thorax exposes the limited ability of conventional radiographs to document fractures of anterior and lower numbered ribs (see Figure 6). The twelve ribs of the thorax are composed of two distinct sections of cartilage and bone. The bony portion of the rib begins at the vertebra and continues until changing to costal cartilage in the most anterior region. The upper seven ribs directly connect, via cartilage, to the sternum and are often referred to as "true ribs". The false ribs, numbered eight (8) through (10), are connected to the costal cartilage of rib seven (7) and thus indirectly connect to the sternum. The osseous (i.e., bony) portion of the ribs falls progressively more lateral to the sternum as rib number increases, resulting in longer costal cartilage regions in anatomically inferior ribs (Clemente, 1987). Henceforth in this paper, ribs 11 and 12 will be excluded from analysis because they do not directly or indirectly connect to the sternum and play little role in rib cage stability.

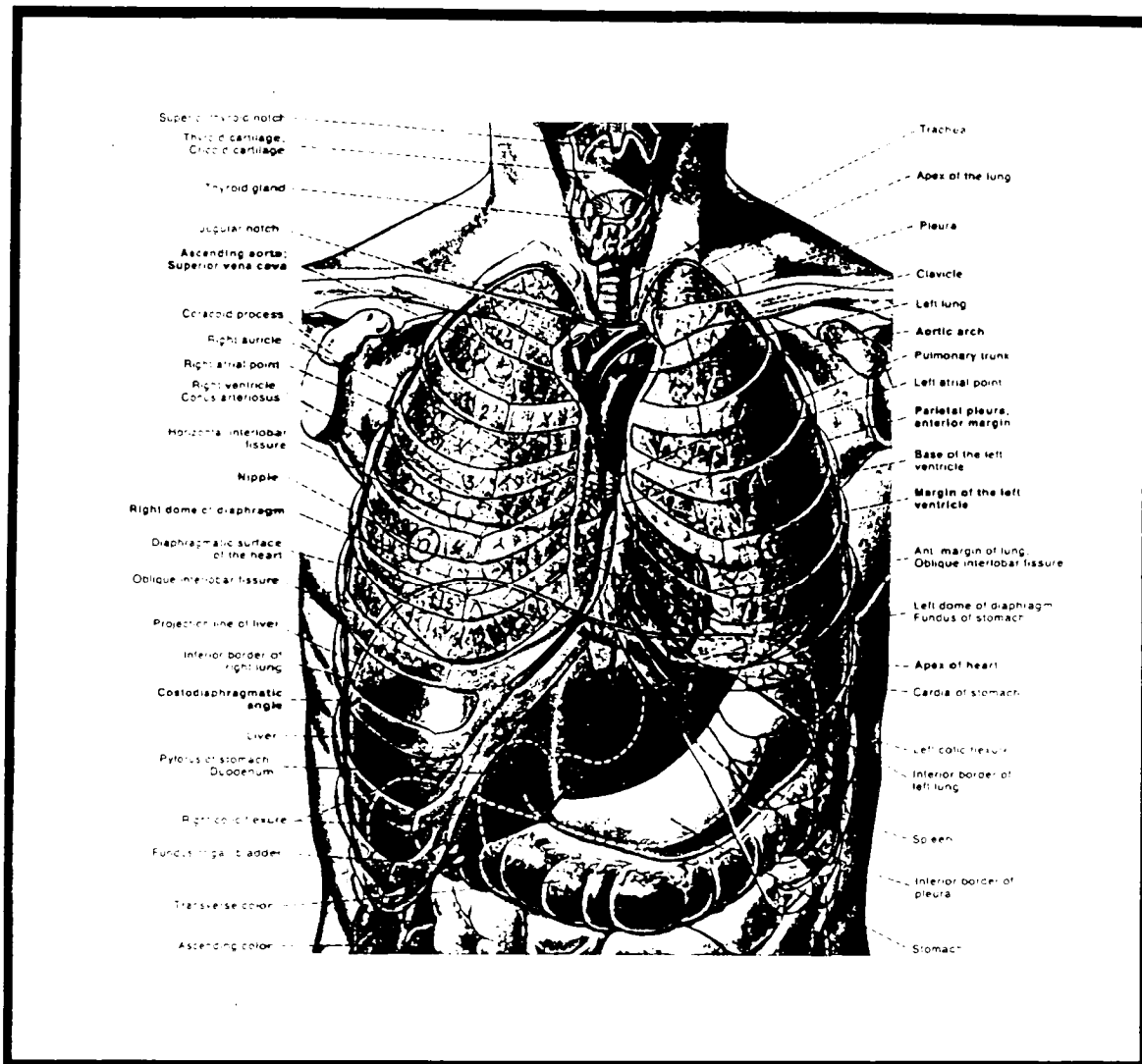


Figure 6. Anatomy of the thorax (Clemente, 1987).

X-ray sensitivity is primarily based on the calcium content of the imaged tissue. The bony portion of the ribs exhibits the standard cortical and trabecular bone structure and thus a high level of calcium. However, the homogeneous costal cartilage region (i.e., anterior region) does not possess consistent calcium deposition; although select, non uniformly distributed deposits can occur. These two sections of rib join at a transition point referred to as the costochondral junction (see Figure 7). Because the cartilage lacks calcium, the anterior region of all ribs is poorly imaged.

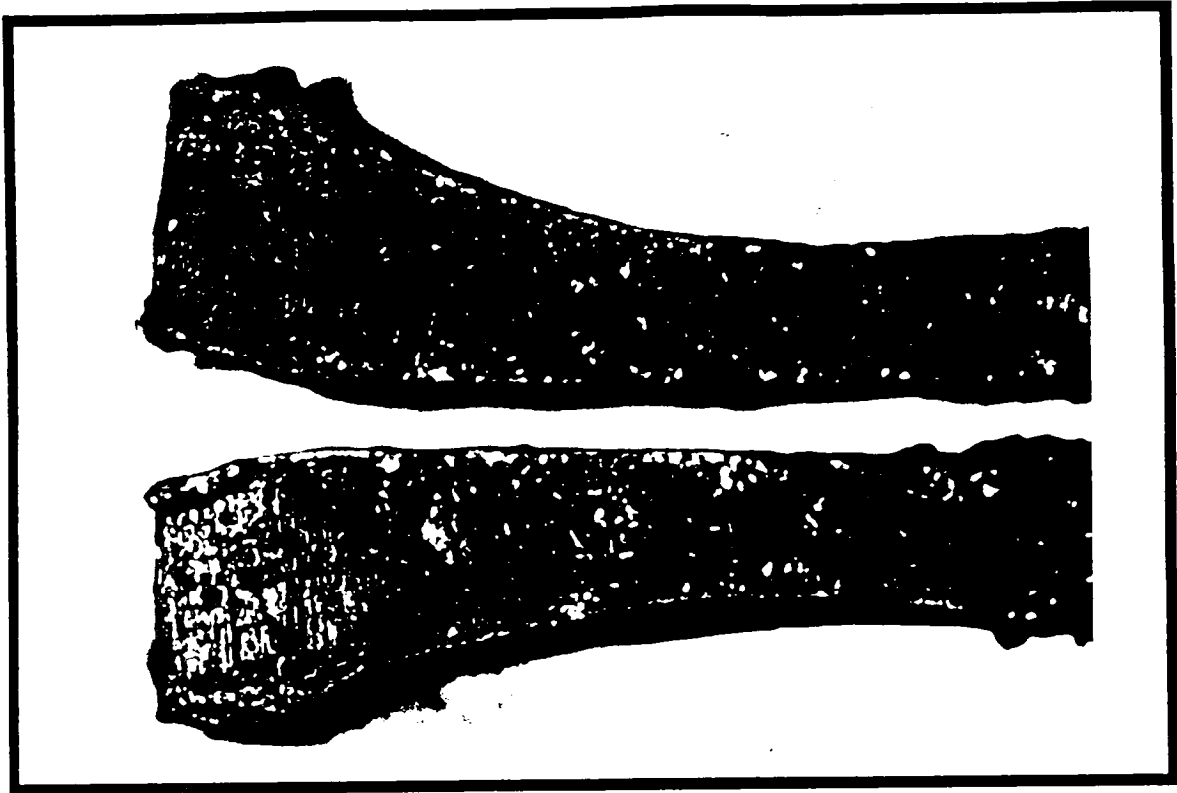


Figure 7. Costochondral junction of the rib

This limitation of x-rays is evident in a typical thoracic x-ray (see Figure 8). Tracing the posterior shaft of the rib starting at the vertebrae around to the front of the thorax, the rib appears to vanish from view. Specifically, the anterior portion of the upper ribs (one through five) is poorly documented in comparison with the lower ribs (six through ten) on the radiograph. This is a result of overexposure due to decreased density of the lungs when compared with the lower abdominal viscera (stomach, liver, spleen, colon, etc.). Due to this density difference and the fact that x-ray is a modality that depicts overlapping tissues, the frontal region of the anatomically lower ribs demonstrate superior imaging.

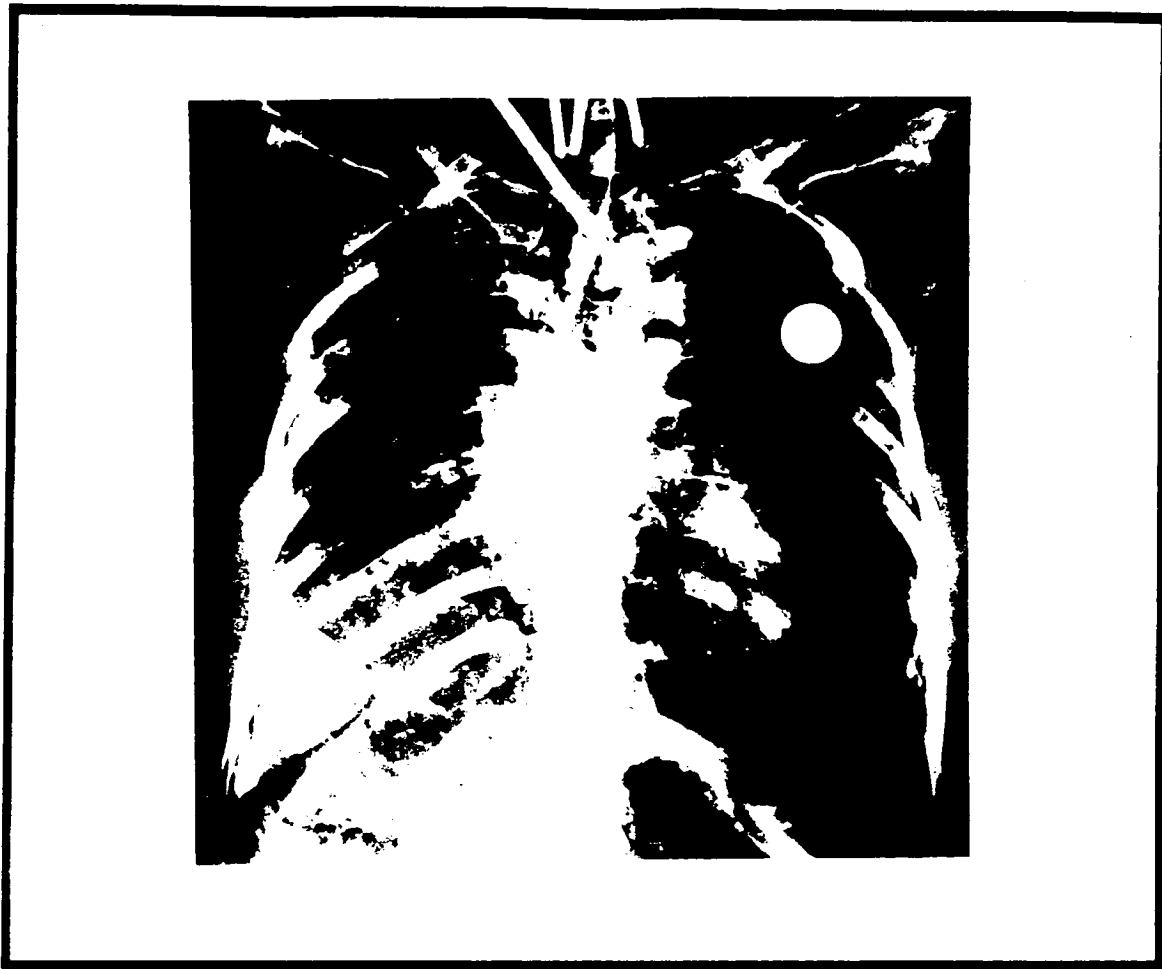


Figure 8. Typical anterior-posterior thoracic radiograph.

To verify that the inability of x-rays to document rib fractures was related to the overexposure and costal cartilage problems, measurements of the costal cartilage region were recorded for several subjects. The distances from the mid sagittal line were taken as typical for the designation of cartilage or poor imaging regions (see Table 2).

Rib Number	Costal Region
1	2.00"
2	1.75"
3	2.25"
4	2.50"
5	3.00"
6	3.50"
7	3.50"
8	4.00"
9	4.25"
10	4.50"

Table 2. Distances from mid sagittal line to costochondral junction

Using the distances from Table 2 and accounting for ribs 1-5 exhibiting overexposure in the anterior region estimated at 3.0" to 4.0" off the midline, the pie charts in Figure 9 were produced.

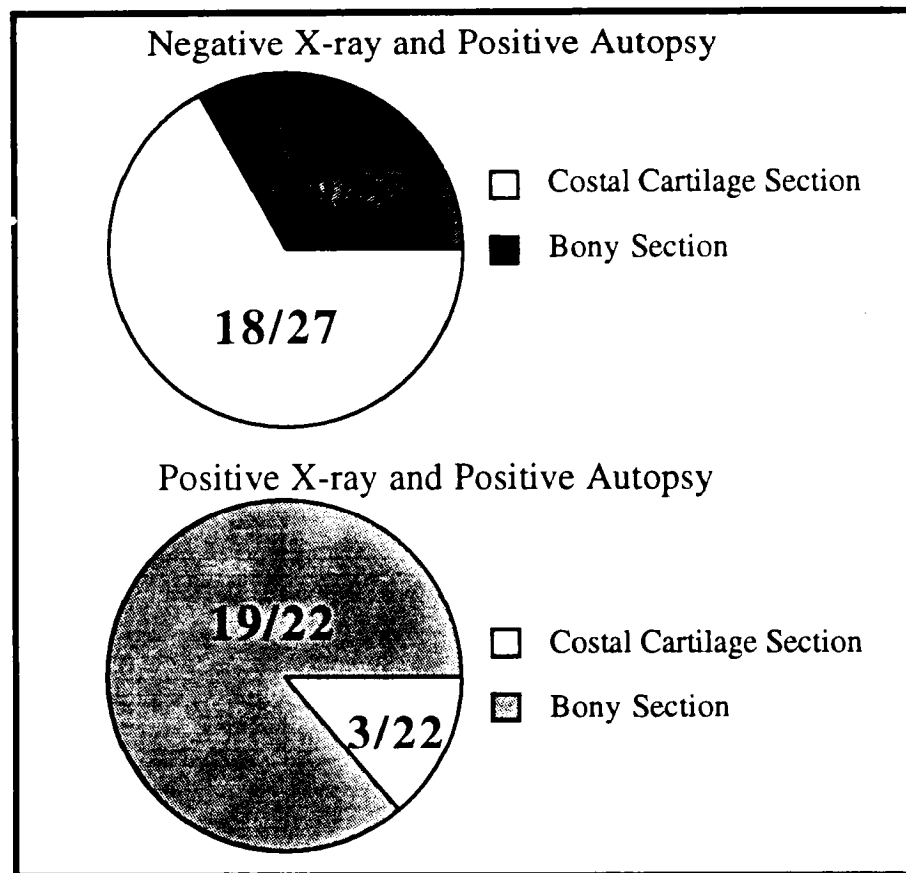


Figure 9. Graph depicting missed fractures due to costal cartilage.

Figure 9 shows the majority of rib fractures which were not correctly identified with radiography (66%) were in the anterior costal cartilage region of the chest. In addition, nearly all the fractures that were accurately documented with x-ray were located in the bony portion of the rib. It is clear that the costal cartilage and

the overexposure due to density differences of the thorax are responsible for a significant number of unreported injuries.

Magnetic Resonance Imaging

Magnetic Resonance Imaging has emerged as a powerful and useful diagnostic tool in clinical medicine. The term resonance implies alternating absorption and dissipation of energy by the body's atoms. Unlike x-ray based modalities, MRI is a non invasive technique that does not subject the patient to doses of radiation. Furthermore, the only tissue specific parameter that can be determined with x-rays or CT is electron density, which does not vary greatly from one soft-tissue to another. MRI, however, incorporates other tissue signal acquisition parameters (e.g., relaxation times) which allow further tissue discrimination.

Nuclei possess a property called spin angular momentum that is the basis of nuclear magnetism. The atomic nuclei are electrically charged due to polarity differences of the protons and neutrons. A spinning motion, resulting from the charge on the nucleus, causes a magnetic moment that is collinear with the spin axis. Hydrogen nuclei, essentially protons, possess the strongest magnetic moment. This strong magnetic moment coupled with the high biological abundance of hydrogen make it the nucleus of choice for MRI imaging. In the absence of an externally supplied magnetic field, the magnetic moments have no preferred orientation and are randomly arranged. If an externally supplied magnetic field is imposed, however, there is a tendency for the magnetic moments to align with the external field.

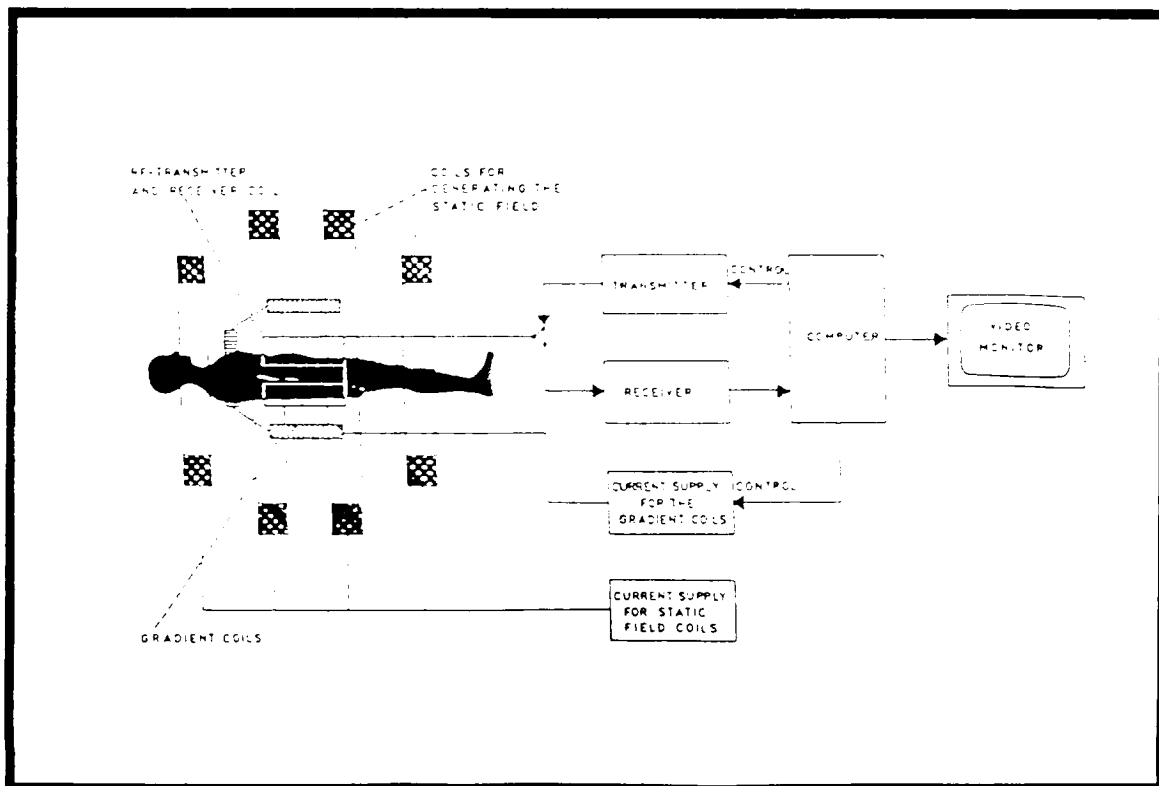


Figure 10. Typical MRI System (Sperber, 1990).

To obtain images, the patient or cadaver is placed in a uniform magnetic field which aligns the body's atoms. These atoms are then perturbed (i.e., displaced from equilibrium) with a radiofrequency pulse and allowed to return to their equilibrium positions. Meanwhile, the signal characteristics such as relaxation time, density, and echo are recorded and translated. Figure 10 illustrates a basic MRI system.

Multiple planes of the body are normally used to obtain the images. Several anatomical views (e.g., axial, sagittal, or coronal slices) can reveal injury and disease unsuspected or undetected in a single view. A three-dimensional grid pinpoints locations of trauma in the body (see Figure 11). In addition, changes in the radiofrequency pulse duration, orientation, and magnitude can further discriminate ill-defined or complex densities and geometries.



Figure 11. MRI coronal and axial images.

Since MRI sensitivity is based upon hydrogen content of tissue, cortical bone that possesses a low water content, is poorly imaged. Therefore, MRI is primarily used to document disease and trauma in soft tissue. Since cadaver tissue responds to the alignment and perturbation process differently than living tissue, we found it necessary to obtain pre-impact and post-impact images. The initial set of images served as a baseline for documenting changes (i.e., trauma) that resulted from impact event.

Computed Tomography

The underlying physics of CT is the same as that of x-rays. CT technology, however, deviates from that of conventional x-rays in that the region to be imaged is examined from multiple angles (see Figure 12). In Computed Tomography, pencil-like photon beams are emitted from strategically placed x-ray tubes. Multiple x-ray tubes and detectors rotate and translate to capture repeated slices at designated locations. This permits improved resolution of anatomic form, discrimination of radiographic density, and ultimately refined characterization of the trauma site (Sperber, 1990).

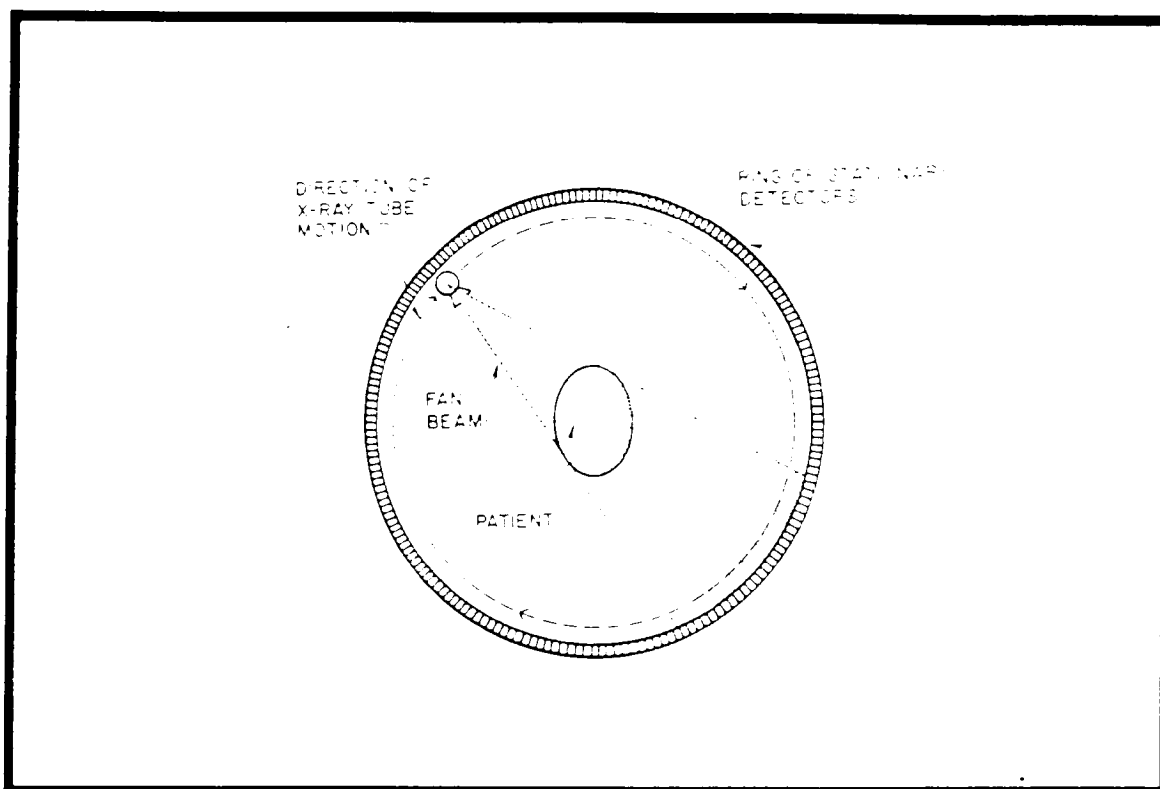


Figure 12. Basic CT System (Curry, 1990)

The detectors do not produce the image but merely add up the energy of all the transmitted photons (Curry, 1990). After detection, the data are digitized and transferred to a computer for storage and analysis. Finally, a two-dimensional image, or slice, composed of multiple projections is produced (see Figure 13).

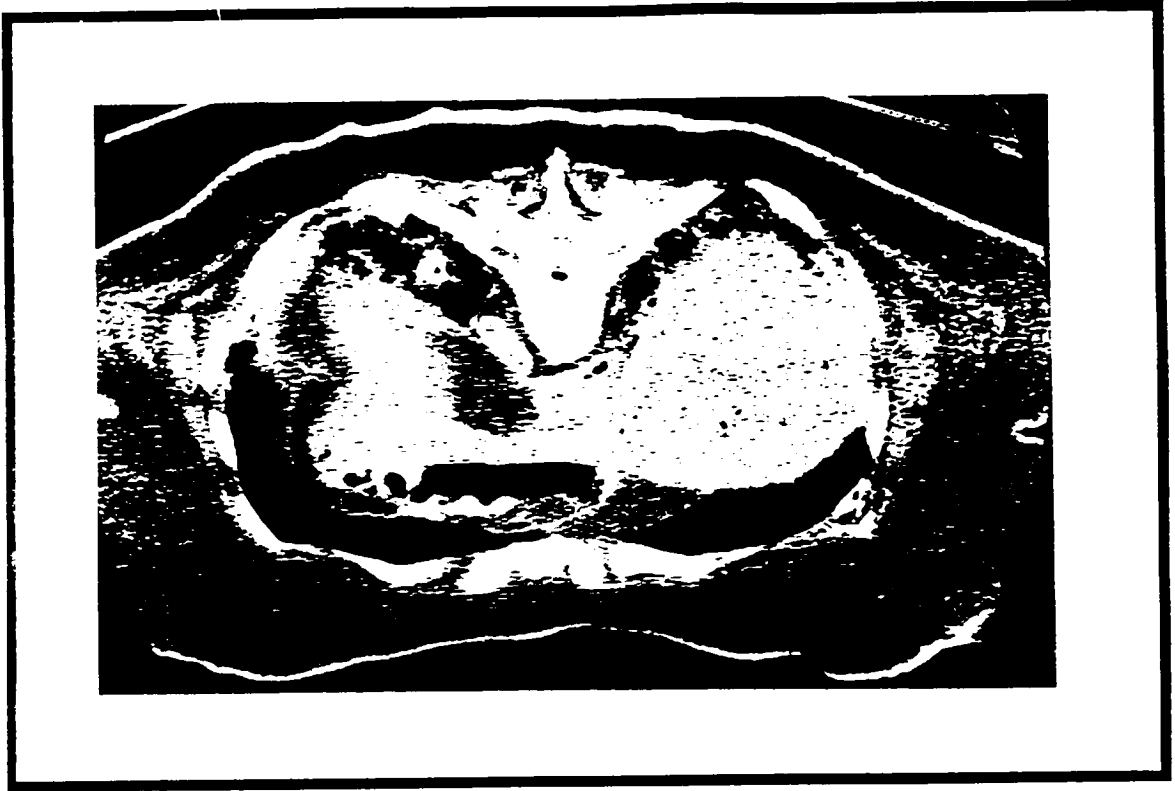


Figure 13. CT axial slice

Technology currently under development permits the internal structure of an object to be reconstructed in three-dimensions. Electron densities of the tissue are averaged over the thickness and assigned throughout the volume of each slice. Finally, an algorithm interprets these data and reconstructs them into a three-dimensional image. Views identical to those used in MRI (e.g., sagittal and coronal) can be constructed from the initial axial images (see Figure 14). By altering window thresholds and contrasts, tissues can be included or eliminated from the viewing region of interest based solely on their densities.



Figure 14. CT three-dimensional reconstructions
Clockwise from top-left corner: topographical, sagittal, coronal, axial

Comparison of Autopsy, X-ray, CT, and MRI Results

In order to compare and contrast the imaging techniques, all three modalities were used to document injuries for UVA subject 92-EF-16. The subject was a sixty-six (66) year old female who had been used in a 30 mph/20 g frontal impact test. Table 3 consolidates the rib fracture data. Since MRI is used primarily to diagnose soft tissue injuries, it is not included in this particular comparison. Autopsy detected 100% of the fractures while CT and x-ray detected 65% and 55% respectively. It is clear from these findings that the autopsy examination must remain an integral part of rib fracture identification.

Rib Number	Right FX No.	Detection	Left FX No.	Detection
2	1	A, X, C	1	A
3	1	A, X, C	1	A, X, C
4	1	A, X, C	1	A, X, C
	2	A		
5	1	A, X, C	1	A, X, C
	2	A	2	A, X
6	1	A, X, C	1	A, X
	2	A		
7	1	A, C	1	A, X, C
8	1	A, C	1	A, C
9	1	A, C	1	A, C
A = Autopsy X= X-ray C = CT				

Table 3: Rib Fracture Data for Subject 92-EF-16

Several other injuries, two sternal fractures and hemo/pneumo thorax, were identified during the autopsy examination of subject 92-EF-16. One sternal fracture was 2.0" proximal to the xyphoid while the other was 4.5" proximal to the xyphoid. Associated with the latter fracture, a transthoracic evulsion of the soft tissue occurred between the anterior fourth and fifth ribs.

By discriminating on the basis of tissue density, the CT images can be reduced to only hard tissue structures (see Figure 15). CT reconstructions successfully documented the sternal fractures and the majority of rib fractures. The displaced sternal and rib fractures were easily identified. From this skeletal image, the three-dimensional locations of the fractures were readily extracted.



Figure 15. CT reconstruction of hard tissue.

X-ray detected a pneumomediastinum but no sternal fractures for subject 92-EF-16. The radiographs identified mildly displaced fractures of the left lateral third, fifth, and seventh ribs (see figure 16). In addition, there were slightly displaced fractures of the right lateral rib numbers two through six. The screws, injection tube, catheter and sternal mount shown in the radiograph were used for pressurization of the cadaver and for securement of the accelerometers to bone.

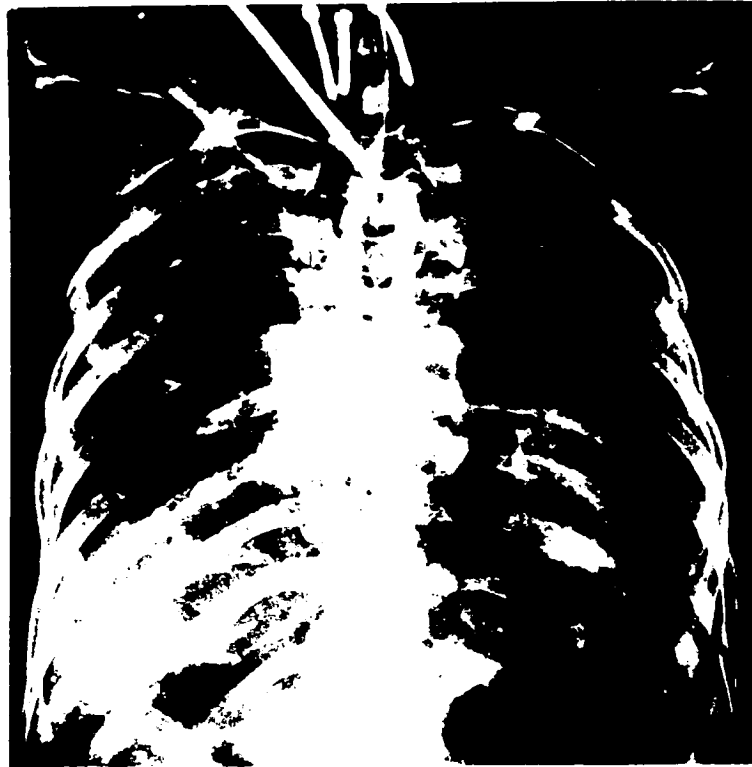


Figure 16. Anterior-posterior thoracic radiograph.

Figure 17 displays the pre-impact and post-impact MRI images for subject 92-EF-16. MRI identified the sternal fractures through detection of the surrounding soft tissue trauma. A disruption of the anterior chest wall involving 3.0" on either side of the midline was noted. Both the fracture and transthoracic evulsion were easily identified, measured, and placed at exact coordinates within the body. Increased post-impact levels of fluid within the lungs, attributable to a combination of the impact event and the post-mortem storage, were also evident.

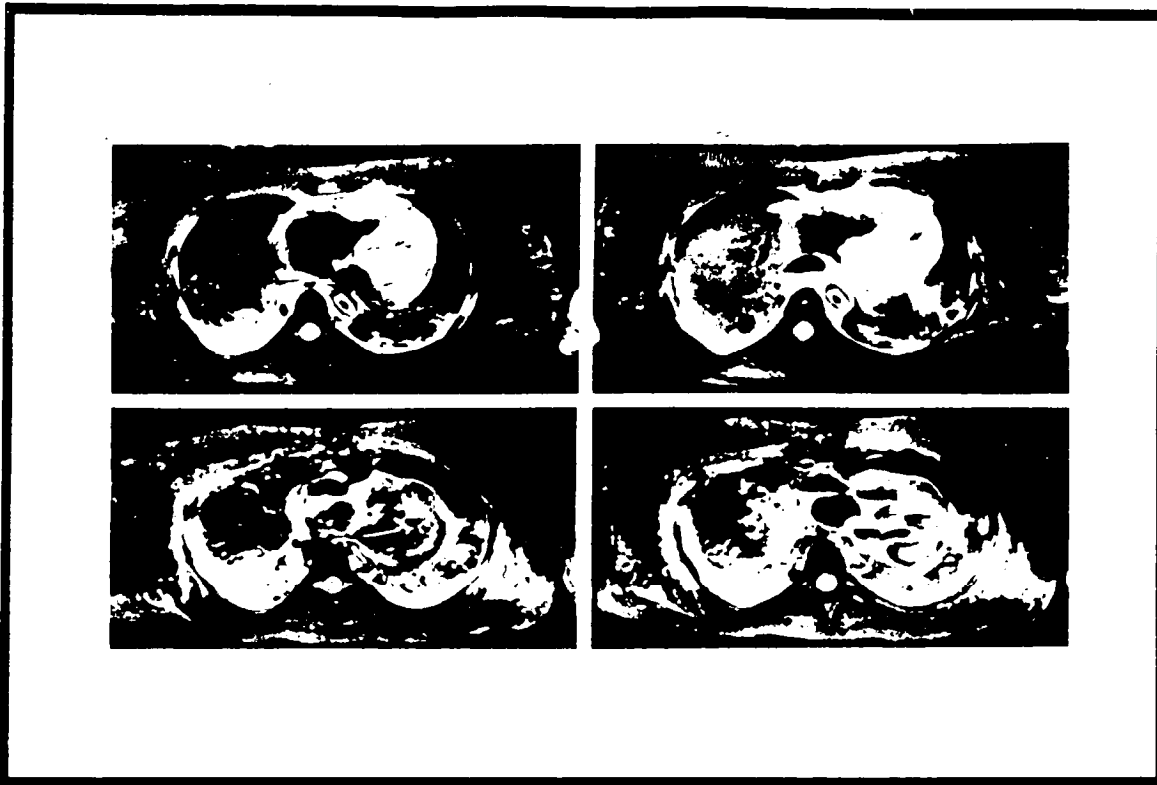


Figure 17. Magnetic Resonance Axial Images of the Thorax for Subject 92-EF-16. Top images are pre-impact. Bottom images are post-impact.

For comparative purposes, the costs for each radiographic modality are provided in Table 4. These figures are valid for research studies only and do not necessarily correlate with the relative cost differences seen in clinical settings.

	X-ray (Whole Body)	CT - Thorax	MRI - Thorax
Pre-Impact	\$500	-	\$500
Post-Impact	\$500	\$300	\$500
Total	\$1000	\$300	\$1000

Table 4 Relative costs of radiographic modalities.

Conclusions

This study demonstrates that x-ray cannot be the sole source of rib fracture identification. Autopsy results were found to be the most exact, detailed, and accurate means of documenting cadaver injuries. The necropsy examination must remain an integral part of any research using human cadavers in an impact environment. X-ray, however, remains the quickest, least expensive, and most convenient modality for initial skeletal screening, positioning of accelerometer mounts, and documenting injuries in body regions other than the thorax. Radiographs of the entire body can be obtained in the same amount of time required for CT or MRI images of only the thoraco-abdominal region.

There are several x-ray techniques currently under investigation at the University of Virginia which may significantly improve the imaging of the cadaver thoracic injuries. Positioning the subject in a prone rather than a supine position during x-rays will place the ribs physically closer to the detecting film. Posterior-anterior radiographs should provide better images of the frontal ribs than the anterior-posterior films currently being used. Because the photons will have to traverse more tissue before reaching the anterior ribs, the lower number ribs should exhibit resolution comparable to that of the higher numbered ribs. Since we have found that the majority of fractures occur near the costochondral junction in the front of the chest, a greater percentage of fractures should be detected. The addition of multifarious views (e.g., lateral and oblique) should also facilitate the identification of hard tissue trauma. X-ray, however, remains a modality of overlapping tissue and the problem persists of poor imaging due to two-dimensional projections of three-dimensional tissue.

The ability of Computed Tomography to discriminate among tissues of varying densities can be a useful tool for injury analysis. CT can also be used as a densitometer to provide an indication of overall skeletal integrity and bone strength. Unlike x-ray films which require interpretation by an adept radiologist, the three-dimensional reconstructions of the skeleton can be easily deciphered by researchers unskilled in the reading of radiographs. The ability to precisely locate injuries within the body permits the correlation of measured engineering parameters with observed trauma at the site of impact. Since CT scans the body with rotating photon tubes and detectors, differences in tissue radiodensities are exaggerated. Organs cannot be readily discerned, however, if surrounded by tissue of comparable density. Since CT does not require a set of pre-impact scans for comparison, the overall cost is quite low (\$300) when compared with MRI (\$1000).

Details of tissues with complex geometries and similar radiodensities can be identified with MRI and not with the other modalities. MRI is truly a multiplanar modality. MRI, unlike CT which averages densities over small volumes, is not limited to axial images which must then be reconstructed to provide three-dimensional representations. The necessity to obtain both pre-impact and post-impact images, however, makes MRI extremely expensive when used to document cadaver injuries. The authors envision using MRI to document soft tissue injuries in cases where the trauma was deliberately administered to a particular region or organ in an impact environment. For example, liver lacerations resulting from blunt impacts could be explicitly documented and correlated with measured engineering parameters. The inability of MRI to identify hard tissue injuries, which are the most prevalent in sled tests with human cadavers, make it an inefficient and expensive modality for injury analysis of entire body regions.

Other radiographic modalities were excluded from this study because they could not identify the types of fractures we were investigating. Nuclear medicine depends on the body's uptake of radioactive isotopes. Since the human cadaver has no active processes, this method was inappropriate for use in our research. Ultrasound could not be used because the sound waves are easily reflected at air-soft tissue interfaces. The chest, containing the lungs, presented too many interfaces for this to a viable technique.

Acknowledgments

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Bibliography

S. Webb, The Physics of Medical Imaging, Adam Hilger, Philadelphia, Pa., 1988.

T. Curry, J. Dowdey, R. Murry, Christensen's Physics of Diagnostic Radiology, 4th Edition, Lea and Febiger, Philadelphia, Pa., 1990.

S. Hiss, Understanding Radiography, Charles C. Thomas, Springfield, Il., 1978.

M. Sperber, Radiologic Diagnosis of Chest Disease, Spriner-Verlag, New York, N.Y., 1990.

C. D. Clemente, Anatomy: A Regional Atlas of the Human Body, Urban and Schwarzenberg, Baltimore, Md., 1987.

DISCUSSION

PAPER: Radiologic Analysis of Cadaver Impact Injuries

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FELLOW AUTHOR: Walter Pilkey from University of Virginia

QUESTION: Frank Pintar, Medical College of Wisconsin

Jeff, I appreciate your analysis. I think we may do a lot more in terms of documenting these kinds of injuries. I was wondering if you considered two things on your x-ray analysis: did you do both AP and P x-rays?

ANSWER: As I said, we've just started doing the PA x-rays. What we've done, traditionally, is we've done an AP and a lateral. But what happens is the reason we are looking at oblique images, and looking at PA, is because if you get a fracture that is a perpendicular point-of-view, you don't pick it up on an x-ray, so we are looking at multi-angles now. We are starting to look at PA. We are starting to look at oblique.

The other thing is that we found that, depending on the severity of the fracture, you can pick it up more on x-rays unless it is a real small fracture that is not displaced, that doesn't break the pleura, you might never pick it up and I don't know if your CT picks it up either, but like the kinds of fractures that you showed were fairly severe, and those kinds of fractures I think you can pick up on x-rays. I think there is very few cases which I've found. In fact, if we looked at some of the other parameters, you will recall in that CAPA test, there is a whole group of parameters we can look at and one of those I believe was the probability that if we found a fracture with x-ray, whether we found it in autopsy or not, and that's a very, very minute number, I think I looked at ten cadavers and I think there were only two cases.

Q: Y. King Liu, University of Iowa

I just wanted to ask you a question concerning the limits of resolutions in terms of lesions you can detect, for example, in CT and MRI. Typically, for example, in the case of CT scan of the head, if the lesions are curved, near the base of the skull, you usually cannot detect it. Whereas, in autopsy, you can see it on the other side. Now what is the state of art at the moment in what you can detect?

A: That's a difficult question for me to answer because we've only looked at the thorax but I know that with MRI, take for example, if you look at the knee ligaments or anything like that, you can see very minute tears. With CT as I said, it doesn't have the differentiation with densities that MRI has, so if you are looking for sub-tissue injuries, I think MRI would give you a pretty good indication and I'm not sure, a radiologist would probably be someone better to answer that.

Q: Oh, I thought you were a radiologist.

A: No. No, I'm actually an engineer.

Q: Jeff Pike, Ford Motor

Can you explain what the relative costs of the three imaging modalities relate to? In other words, their costs, that wouldn't be patient costs.

A: Those were complete costs for us including tech time, including supplies, including renting the facility or whatever. Can you help me out beyond that what you want?

Q: I'm trying to explain what I thought I meant. I was inquiring as to, we saw the relative cost of the different imaging fatalities.

A: Yes.

Q: And I'm just trying to put it into perspective. If that relates to the types of typical costs that someone might incur who is going to do one cadaver or if it was sort of an in-house rate, that type of thing.

A: This pretty much is an in-house rate. These were done at the University of Virginia and Health Sciences Center. What you'd see for say a typical thoracic abdominal scan in a patient would be somewhere between \$1,500 and \$1,800, what we would charge \$500 for. We don't have a long term agreement or anything like that. This was just a one time or several time deal with the Health Science Center. With CT, I think they give us a special research rate which is pretty standard within the hospital and then with x-ray, we do have an on-going agreement and that is a long-term contract. Does that answer your question?

Q: Yes.

A: OK.

Q: Jim McElhaney, Duke University

We're doing similar things next and we could cause injuries too from cadavers and just a thought. We're able to get our MRI's done free because we've convinced the radiologists to do that. They can learn to read MRIs and trauma in ways that they don't have available to them, so we convinced them that we'll do the autopsy, which is the gold standard and then they read the MRI and CTs and we compare notes and they learn from us.

A: That's very interesting.

Q: This is one of the rare times when we're able to feed something back in to the medical profession.

A: That's very interesting.